Effects of a Breach Fill Maintenance Project on Benthic Communities in Half Moon Bay, Westport, WA

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Abstract
Beneficial reuse of dredged material can be an attractive alternative to open water disposal at dredged material disposal sites. In 2004, a pilot study was conducted in Half Moon Bay, Westport, Washington, to measure the impact of a breach fill maintenance project on the intertidal and subtidal benthic communities in this Pacific coastal region. Placement of approximately 25,000 cubic yards of sand was needed to stabilize the sand spit adjacent to the Grays Harbor south jetty, thus protecting both the south jetty and federal navigation channel. Benthic invertebrate surveys in Half Moon Bay were conducted in January 2004, prior to fill placement, and in early summer (June 2004) after breach maintenance. The sampling design included intertidal and subtidal locations along four transects within the Bay and two transects in South Beach. South Beach was evaluated as a potential reference site. Benthic samples were collected, preserved, and rinsed through nested sieves of three size classes (1.0 mm, 0.5 mm and 0.25 mm). In addition, a limited study on fish gut content in Half Moon Bay was conducted to assess the importance of Half Moon Bay as a feeding area during juvenile salmonid migration. Results of the survey are presented, and the implications for the effects of the breach fill maintenance project are discussed.

Introduction
In February 2004, the U.S. Army Corps of Engineers, Seattle District (USACE) placed approximately 25,000 cubic yards of sandy dredged material along a 700-foot long stretch of shoreline in Half Moon Bay, Westport, Grays Harbor County, Washington (Figure 1). Accelerated erosion in Half Moon Bay threatens the fill placed at the south jetty where a breach occurred in 1994, and which was also re-nourished in 2002 (USACE 2004a). The interim sand placement in 2004 was intended to prevent another breach from forming and threatening the stability of the south jetty and federal navigation channel until a long-term maintenance strategy is implemented. The goal of this pilot study was to assess whether the sand placement in February 2004 had altered or impacted the structure and function of the intertidal and subtidal benthic infaunal communities in Half Moon Bay. An additional goal of the study was to assess the relative importance of Half Moon Bay as a feeding area for juvenile Chinook salmon during outmigration.

Sampling Methods
Two benthic invertebrate surveys were conducted at Half Moon Bay and South Beach: a baseline survey on January 20 and 21, 2004, prior to the placement of the maintenance fill material and a post-placement survey on June 29 and 30, 2004 (early summer). During each sampling event, intertidal core samples were collected at thirteen sample sites from western Half Moon Bay and eight sites on South Beach (Figure 1). Samples were collected from South Beach to evaluate its suitability as a reference site. Intertidal benthic samples were collected at four elevations (+12 feet, +8 feet, +4 feet, and 0 feet MLLW) and were collected by hand at low tide. Subtidal core samples were collected from eight sample sites in western Half Moon Bay. Subtidal benthic samples were collected at high tide from three elevations (-4 feet, -8 feet, and -12 feet MLLW) using a modified 0.1 m^2 Young van Veen sampler deployed from the M/V *Shoalhunter.*

Ten replicate core samples were collected at each intertidal and subtidal station. The samples were collected using a cylindrical coring device 5 cm in diameter and 15 cm long. For subtidal samples, the coring device was inserted into the van Veen sampler to collect samples similar in size to the intertidal samples. A minimum of three replicates from each station were analyzed for benthic infauna. For three of the Half Moon Bay stations, all ten replicates

BACK

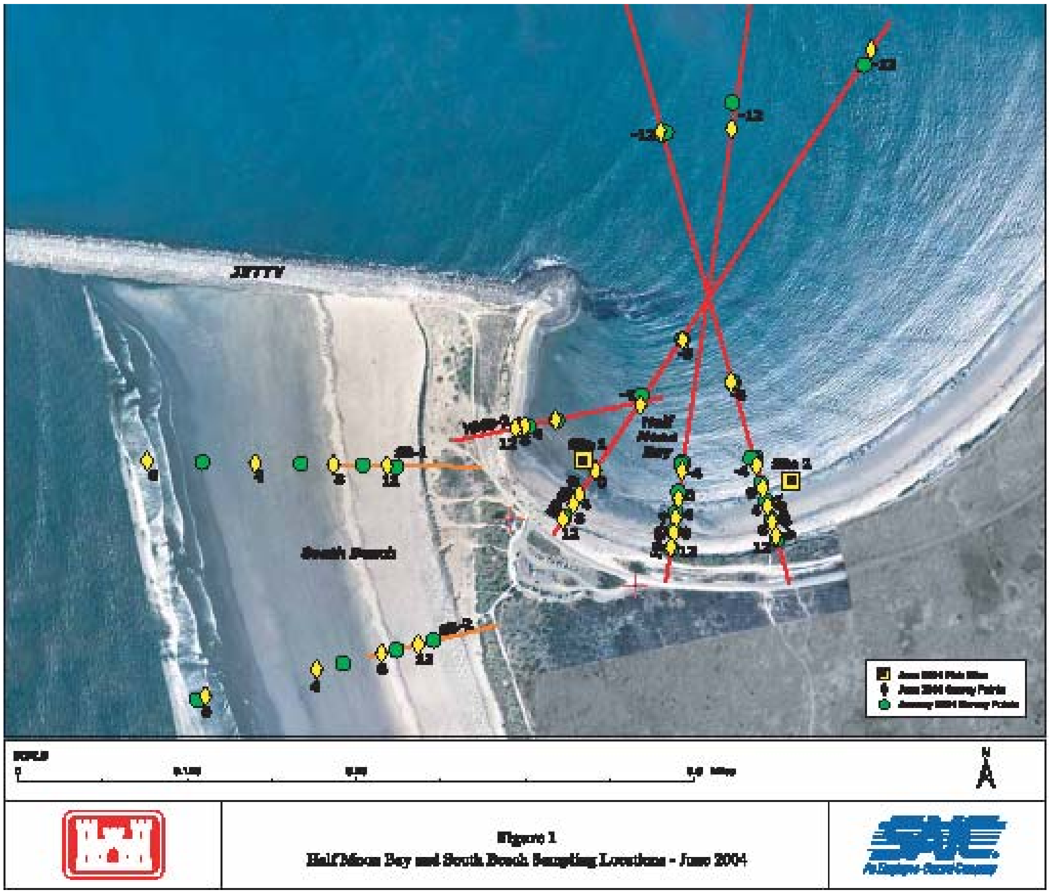

Figure 1. Half Moon Bay and South Beach sampling locations for the January and June 2004 surveys.

were analyzed to evaluate whether the benthic infauna data was normally distributed with ten replicates. Samples to be analyzed were washed through a series of nested sieves of 1.0 mm, 0.5 mm, and 0.25 mm. The following were determined for each sample: the number of individuals for each species, total number of individuals, number of individuals by major taxa, total wet weight biomass, and wet weight biomass by major taxa. A separate sediment sample was also collected and analyzed for grain size at each intertidal and subtidal station.

Results

The data collected in January and June 2004 was analyzed for benthic community structure. A detailed presentation of the benthic infauna analysis results can be found in USACE (2004b, 2004c). Biological endpoints were calculated to reduce the data into simple numerical relationships for descriptive purposes and for comparison between data sets. The biological data from each station was summarized by pooled abundance, mean, and standard deviation. The following endpoints were selected for analysis because they are sensitive to detecting changes in benthic communities due to human activity and natural environmental stresses (Striplin and Musgrove 1999):

- Abundance, numbers of taxa (richness), and biomass
    - Total
    - Annelida
    - Arthropoda
    - Mollusca
    - Miscellaneous
- Dominant taxa at each station

BACK

Benthic Community Characterization

The mean total abundance and total number of taxa for Half Moon Bay and South Beach are shown in Figure 2. In January, the total abundance and numbers of taxa in the intertidal zone (+12 to 0 feet MLLW elevation) were relatively low for both Half Moon Bay and South Beach. In June, the intertidal stations in South Beach showed a greater increase in total abundance than the intertidal stations in Half Moon Bay. The low intertidal stations at Half Moon Bay (0 feet elevation) contain the highest abundance and numbers of taxa of all Half Moon Bay intertidal stations, but the average abundance was still 1/3 of that found at the South Beach intertidal stations.

With the exception of station HMB2 +0, the total number of taxa and the taxa representing the major taxonomic groups were similar between Half Moon Bay and South Beach. Although the number of taxa doubled at station HMB2+0, the dominant taxa (Nemertea indet.) remained the same. At the subtidal stations (-4 to -12 feet MLLW elevation) in Half Moon Bay[1], abundance and taxa richness increased substantially between January and June. The highest mean total abundance was measured at the -12 feet MLLW elevation. Increasing abundance and number of taxa are expected in the subtidal because more organic material is available in deeper water, which acts as a food source for benthic organisms. The subtidal stations are also more isolated from extreme environmental and climatic shifts to which organisms in the intertidal zones are exposed.

At both Half Moon Bay and South Beach stations the percentage of juveniles generally increased with increasing water depth, with virtually no juveniles being present at the +12 feet stations. With the exception of stations along the +4 feet elevations, there were a greater percentage of juveniles at South Beach than at Half Moon Bay. In both study areas the major taxonomic group that contained the greatest percentage of juvenile organisms was the miscellaneous phyla (dominated by Nemertea indet.). The proportion of juveniles in both locations is more than likely the result of the sampling period. The months of May and June are the greatest period for planktonic activity and juvenile recruitment from the water column to the benthos.

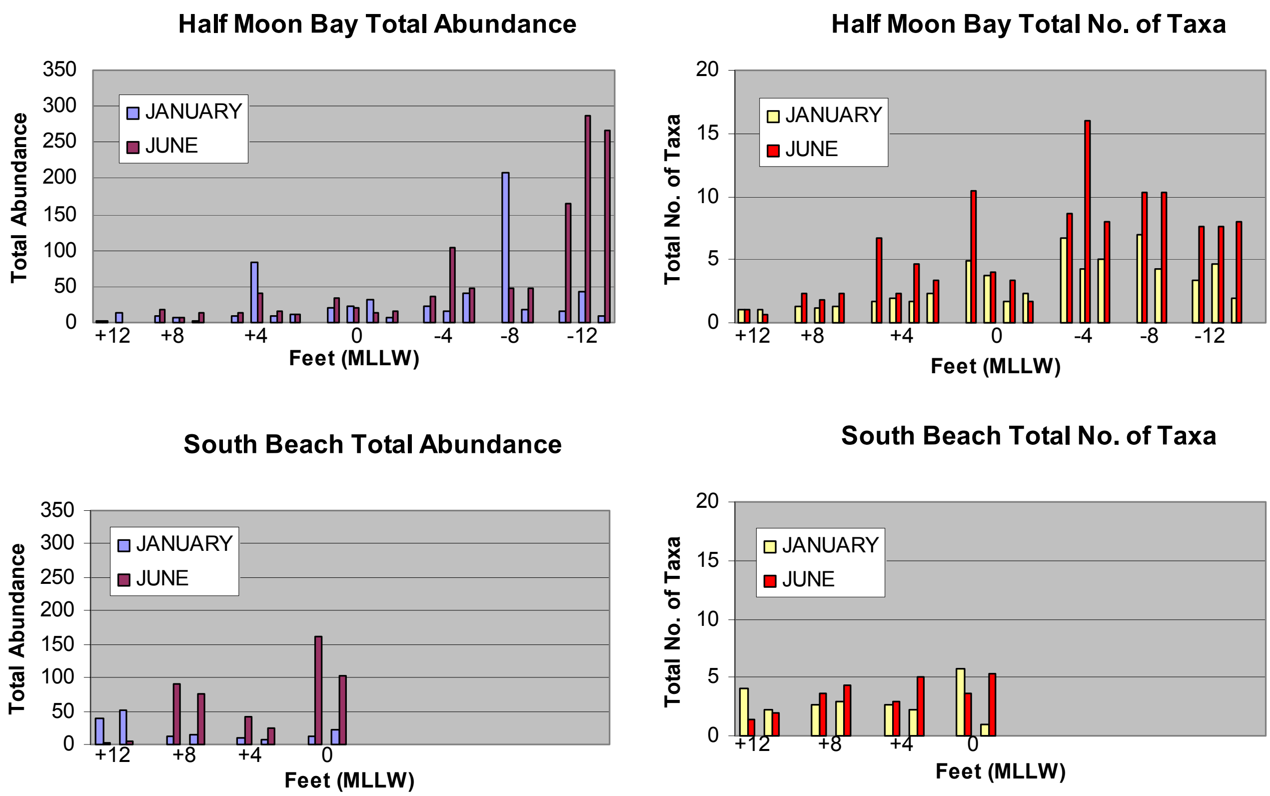

Figure 2. Mean total abundance and number of taxa per sample for Half Moon Bay and South Beach stations, sorted by elevation.

[1] Subtidal stations were not sampled in South Beach due to vessel sampling limitations.

Data Analysis

Statistical testing was conducted using the SYSTAT statistical software package (SYSTAT, Ver.11). Three methods were used to compare benthic community data between the sampling periods of January and June. The first method was the Pierson correlation analysis comparing three measures of sediment grain size to benthic community endpoints. The second method was the Kruskal-Wallis one-way analysis of variance[2]. This nonparametric test orders the data by rank and determines whether the center points of each population differ from the others. When there are only two groups (i.e., one degree of freedom) as in the case of the January and June sampling periods, the procedure in the SYSTAT software calculates the Mann-Whitney U test and reports those results. The third method combines a description of the dominant taxa and a subjective comparison between the two sampling periods. A detailed presentation of the benthic infauna analysis results for the January and June 2004 benthic surveys conducted in Half Moon Bay can be found in USACE (2004b, 2004c).

Pierson's Correlation Analysis

Pierson's correlation analysis was conducted to determine the relationship between the benthic community endpoints and three measures of sediment grain size: percent gravel, sand and fines. A coefficient of +0.7000 was used as the level at which a relationship was deemed to be significant. A comparison of the total number of positive correlations between the intertidal stations (0, +4, +8, and +12 feet MLLW) and subtidal stations (-4, -8, and -12 feet MLLW) is summarized in Figure 3. In the intertidal, the benthic infauna was predominantly correlated to percent fines in both January and June. In the subtidal, the benthic infauna was predominantly correlated to percent gravel in January and to percent fines in June. Correlation analysis for the South Beach data was not useful because grain size was found to be nearly 100 percent sand at all intertidal elevations, and only two stations per intertidal elevation were sampled.

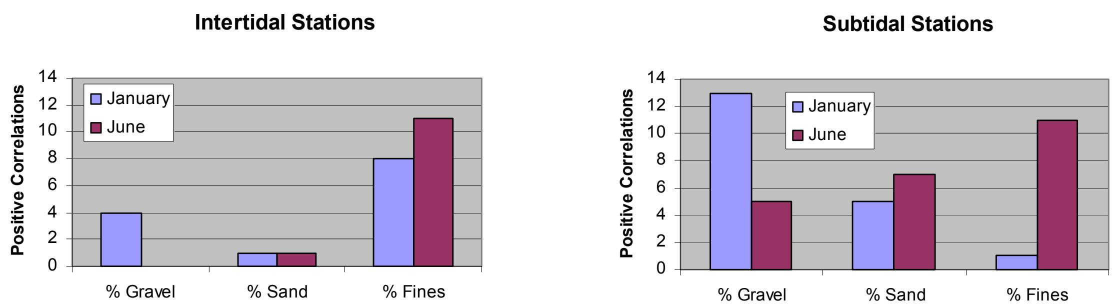

Figure 3. Summary of positive correlations between grain size and benthic community endpoints in Half Moon Bay.

Kruskal-Wallis Analysis of Variance

The summarized results from the Kruskal-Wallis one way analysis of variance are presented in Table 1. The analysis calculated 15 benthic community endpoints at 29 stations and compared the results from samples collected in January 2004 to those collected in June 2004. A total of 315 tests were conducted with the Half Moon Bay data and 120 tests were conducted with the South Beach data. The results were summarized by the number of stations and by the number of endpoints that showed no significant difference (NS), endpoint data where the abundance and numbers of taxa in June were significantly greater than (α=0.05) in January (S+), and endpoint data that showed samples collected in June were significantly less than (α=0.05) those sampled in January (S-).

For Half Moon Bay, 77 percent of the tests showed no significant difference between the January and June sampling periods. The majority of tests (66 percent) for South Beach also showed no significant difference, but at a smaller percentage than Half Moon Bay. The difference can be attributed to the tests conducted along the +12 feet MLLW elevation in South Beach, where 40 percent of the tests were significantly less in June than in January.

[2] For data comparability, all statistical analysis was conducted using nonparametric tests.

Table 1. Results of the Kruskal Wallis one way analysis of variance comparing endpoint data from stations sampled in January to those sampled in June 2004.

Station	Total Biomass	Miscellaneous Biomass	Mollusca Biomass	Arthropoda Biomass	Annelida Biomass	Total Abundance	Miscellaneous Abundance	Mollusca Abundance	Arthropoda Abundance	Annelida Abundance	Total No. of Taxa	Miscellaneous No. Taxa	Mollusca No. Taxa	Arthropoda No. Taxa	Annelida No. Taxa	No Significant Difference	S+	S -
HMB4+12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	15	0	0
HMB5+12	S -	S -	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	13	0	2
SB1+12	S -	NS	NS	S -	NS	S -	S -	NS	S -	S -	S -	NS	NS	S -	NS	7	0	8
SB2+12	S -	S -	NS	NS	NS	S -	S -	NS	NS	NS	NS	NS	NS	NS	NS	11	0	4
HMB3+8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	15	0	0
HMB4+8	NS	NS	NS	NS	NS	NS	S -	NS	NS	S+	S+	NS	NS	NS	S+	11	3	1
HMB5+8	NS	S+	NS	NS	NS	S+	S+	NS	NS	NS	NS	NS	NS	NS	NS	12	3	0
SB1+8	NS	S+	NS	S+	NS	S+	S+	NS	S+	NS	NS	NS	NS	NS	NS	10	5	0
SB2+8	S+	NS	NS	S+	S+	S+	S+	NS	S+	S+	NS	NS	NS	NS	NS	8	7	0
HMB2+4	NS	NS	NS	NS	NS	NS	NS	NS	NS	S+	S+	NS	NS	NS	S+	12	3	0
HMB3+4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	15	0	0
HMB4+4	NS	S+	NS	NS	NS	S+	NS	NS	NS	S+	NS	NS	NS	NS	S+	11	4	0
HMB5+4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	15	0	0
SB1+4	NS	NS	NS	NS	S+	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	14	1	0
SB2+4	S+	NS	NS	S+	S+	NS	NS	NS	NS	S+	S+	NS	NS	NS	S+	9	6	0
HMB2+0	NS	S+	NS	NS	NS	NS	NS	NS	S+	NS	S+	S+	NS	S+	NS	10	5	0
HMB3+0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	15	0	0
HMB4+0	NS	NS	NS	NS	NS	NS	S -	NS	NS	S+	NS	NS	NS	NS	NS	13	1	1
HMB5+0	NS	NS	S -	NS	NS	NS	NS	S -	NS	NS	NS	NS	S -	NS	NS	12	0	3
SB1+0	S -	S+	S -	NS	NS	S+	S+	S -	NS	NS	NS	NS	S -	NS	NS	8	3	4
SB2+0	NS	NS	NS	NS	NS	S+	S+	NS	NS	NS	S+	NS	NS	NS	NS	12	3	0
HMB3 -4	NS	NS	NS	NS	S+	S+	NS	NS	NS	NS	NS	S -	S -	NS	S+	10	3	2
HMB4 -4	NS	S -	S -	NS	NS	S+	NS	S+	S+	S+	S+	NS	S+	S+	S+	5	8	2
HMB5 -4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S+	NS	NS	NS	NS	14	1	0
HMB3 -8	NS	S -	NS	NS	NS	S -	NS	NS	NS	S -	NS	NS	NS	NS	NS	12	0	3
HMB5 -8	NS	NS	S+	S+	NS	S+	NS	S+	S+	S+	S+	NS	S+	S+	S+	5	10	0
HMB3 -12	S+	NS	NS	NS	NS	S+	NS	NS	NS	S+	S+	NS	NS	NS	NS	11	4	0
HMB4 -12	NS	NS	S+	S+	NS	S+	NS	S+	S+	S+	NS	NS	S+	S+	NS	7	8	0
HMB5 -12	S+	NS	NS	NS	S+	S+	S+	NS	NS	S+	S+	NS	NS	NS	S+	8	7	0
No Significant difference	21	20	24	23	24	14	19	24	22	16	18	27	23	24	21	320		
S +	4	5	2	5	5	12	6	3	6	11	10	1	3	4	8		85	
S -	4	4	3	1	0	3	4	2	1	2	1	1	3	1	0			30

S+ (green shade) indicates the June data were significantly enhanced (α = 0.05) over January data.
S - (gray shade) indicates the June data were significantly depressed (α = 0.05) from those sampled in January 2004.
NS indicates no significant difference between June and January 2004.

BACK

Enhancement in community endpoints was similar in Half Moon Bay and South Beach with 21 percent and 19 percent significant enhancement, respectively. Endpoint decreases were higher in South Beach, with 13 percent showing significant decreases versus 4 percent in Half Moon Bay.

Overall, the comparisons indicated that the stations from Half Moon Bay were fairly evenly split between one season being enhanced over the other. Of the benthic community endpoints, 77 percent of the comparisons showed no significant differences between the two sampling periods. Although the majority of benthic community comparisons in South Beach (66 percent) also showed no significant differences between January and June, a high proportion of comparisons showed significant decreases along the +12 feet MLLW elevation. This correlates to a significant decrease in total abundance observed between January and June (Figure 2). The difference is likely related to different physical dynamics at South Beach. South Beach is a gently sloping beach that is exposed to the open coast, whereas Half Moon Bay is a semi-protected embayment with a steeper sloping beach. During the summer months, the upper intertidal in South Beach is likely exposed for longer periods of time and exposed to warmer temperatures, which makes it less hospitable to benthic organisms.

Dominant Taxa

In January and June, the dominant taxa in Half Moon Bay were the Nemertea indet. Nemerteans dominated the infauna in 17 of 21 stations in January and 18 of 21 stations in June, and were the subdominant taxa at the remaining stations. The polychaete *Saccocirrus* sp. was dominant at two of the January stations and the three stations in June. This species of archiannelid is found living between grains of sand and among algae and is considered to be meiofauna. The oligochaete *Marionina* sp. and the copepod Harpacticoida indet. were the dominant organisms in the two remaining January stations. Like the polychaete *Saccocirrus* sp., *Marionina* sp. is considered to be meiofauna and lives interstitially between sand grains in the high intertidal zone.

The number of species that could be considered dominant or subdominant increased from the high intertidal to the low subtidal. Along the +12 feet MLLW elevation, only Nemertea indet. and *Marionina* sp. were abundant enough to be considered dominant. Nemerteans and oligochaetes were also the two dominant taxa along the +8 feet MLLW elevation. Five dominant taxa were present along the +4 feet MLLW elevation, including nemerteans, oligochaetes and three taxa of polychaetes. From the 0 to -12 feet MLLW elevation, the number of dominant and subdominant taxa greatly increased. This number ranged from 8 taxa at the 0 feet MLLW elevation to 12 taxa at the -12 feet MLLW elevation. Beginning at the 0 feet MLLW elevation, harpacticoid copepods, amphipod crustaceans, and small bivalve Mollusca were present. The larger species of polychaetes were also present along these subtidal elevations. The larger species, which were not considered to be meiofauna, were both tube building and free living forms.

The predominant taxa at the South Beach stations were essentially the same as those in Half Moon Bay. The nemerteans strongly dominated all eight intertidal stations. In a pattern similar to Half Moon Bay, the subdominant taxa at +12 feet MLLW elevation was the oligochaete group. The subdominant species at Stations SB1 +8 and SB2 +8 was the amphipod *Eohaustorius brevicuspis*. While oligochaetes were present along the +8 feet MLLW elevation, they were only found in abundance at Station SB2 +8 during the June sampling period. A clear subdominant species was not observed at the +4 feet MLLW elevation. The polychaete *Nephtys californiensis* was found at both stations but only during the June sampling period. The amphipod *Eohaustorius washingtonianus* was also found at both stations and with a similar abundance to *Nephtys* but only during the January sampling. Unlike the stations in Half Moon Bay, a greater diversity of dominant and subdominant species is present higher in the intertidal zone at the South Beach stations. A greater number of polychaetes and amphipod crustaceans were present at South Beach in comparison to comparable elevations in Half Moon Bay. Conversely, fewer juvenile molluscs were found to be subdominant at the South Beach stations. The only mollusc identified at South Beach as dominant was *Siliqua patula* at Station SB1 +0 in January 2004.

Fish Gut Content Analysis

The stomach content of fish present in Half Moon Bay was analyzed to determine whether the fish are using Half Moon Bay as a feeding area, particularly for juvenile Chinook salmon during their outmigration. Beach seining was conducted in June 2004 to collect fish at two Half Moon Bay sites (Figure 1). In addition to Chinook salmon, other species collected for stomach content analyses included surf smelt, sandlance, American shad, shiner perch, English sole, speckled sanddab, and sand sole. The most prevalent invertebrates consumed by juvenile Chinook salmon were not abundant in the Half Moon Bay benthic community. *Jassa* sp. were the dominant organism in salmonid gut content (73%). *Jassa* species are tube dwelling amphipods, a known fouling organism that inhabits flotsam (e.g. kelp and driftwood), pilings, and boat hulls. Stomach content for the forage fish species (herring, shad, surf smelt, and sandlance) was dominated by water column organisms, with very little predation on benthic community organisms. Of the flatfish species, English sole was the most common flatfish present in Half Moon Bay. Stomach content analysis showed that these flatfish appeared to be feeding on polychaetes that were derived from mid and lower intertidal elevations in Half Moon Bay.

Half Moon Bay provides suitable habitat for intertidal and subtidal benthic communities, but does not appear to support a significant food source for fish species within Half Moon Bay, with the exception of English Sole.

Discussion

Benthic Community Comparison between Surveys

The Pierson correlation analysis appeared to indicate that the benthic communities in Half Moon Bay were highly correlated to percent gravel in January and to percent fines in the June sampling period. This result is to be expected and may not be related to beach fill maintenance. The physical environment at Half Moon Bay can be very dynamic during the January time frame with greater current speeds and higher wave activity. Fine particulate materials would not settle to the sediment surface and thus would not be available for the benthic community as a food source. In contrast, water movements and wave heights would be much less in June. Fine particulate material would settle to the sediment surface and be available as a food source. A dynamic shift in the benthic community was not observed between the two sampling periods based on the numbers and types of species present during both surveys and by the dominant taxa groups.

The Kruskal-Wallis analysis of variance compared the endpoint data from stations sampled in January 2004 to the same stations sampled in June 2004. A total of 435 endpoint comparisons were conducted for Half Moon Bay and South Beach. The majority of comparisons showed no significant difference between the January and June surveys. In Half Moon Bay, 77 percent of the comparisons showed no significant difference between the two sampling periods compared to 66 percent showing no significant difference in South Beach. Of the remaining endpoint comparisons, a higher proportion showed significant increases from January to June than significant decreases. Based on the benthic endpoint comparison, beach fill maintenance has not substantially altered the benthic community at Half Moon Bay.

The biomass data for both sites indicated that arthropod and annelid biomass was slightly enhanced in June while enhancements in the total, miscellaneous, and mollusc biomass were evenly split between the two periods. The arthropod and annelid biomass results could be attributed to the recruitment and settlement of juveniles to the surrounding environment. The total abundance endpoint identified 41 percent of the stations as enhanced in June, which can be attributed to the abundance of annelids where 38 percent of the stations were identified as enhanced.

Dominant Species

The predominant species at nearly all stations in Half Moon Bay and South Beach was the Nemertean ribbon worm. The majority of the subdominant taxa at both intertidal and subtidal stations were very small organisms that are considered meiofauna. These organisms occur interstitially between sand grains feeding on small pieces of organic material that are trapped there. These species include archiannelids, oligochaetes, and harpacticoid copepods. Juvenile organisms from the phyla Annelida, Arthropoda, and Mollusca made up the remainder of the dominant and subdominant in both sampling areas. The primary difference between Half Moon Bay and South Beach was the diversity of the dominant species. There was a greater number of taxa that could be considered as dominant at the majority of South Beach stations, at all but in the high intertidal zone. To identify difference in the seasonal abundance of the dominant taxa, the abundance of nemertea was examined. This species group was present consistently at all stations during both sampling periods. While there did appear to be some trend showing a greater abundance of nemerteans in June, it was not conclusive at either the intertidal or subtidal stations in Half Moon Bay. Conversely, this trend was clear at all but the two +12 feet elevation stations in South Beach.

CONCLUSIONS

The benthic infaunal communities in Half Moon Bay were disrupted by the placement of maintenance fill to shore up the south jetty. This disruption appears to have been short lived and the recovery of the benthic community is proceeding as expected. This conclusion is based on the large number (77 percent) of benthic endpoints that showed no significant differences between the January sampling (pre-disposal event) and the June sampling (post-disposal event). In addition, 19 percent of the endpoints indicated that the benthic community sampled in June was enhanced over the sampling that occurred pre-disposal, while only 4 percent of the endpoints indicated that the community was depressed post disposal. Many of the differences noted between the two sampling periods could very well be attributed to the recruitment and settlement of juvenile organisms to the benthic community. Furthermore, the dominant and subdominant taxa at stations pre and post-maintenance fill were virtually the same, and were present at similar abundances in both seasons.

Stomach content analysis of fish present in Half Moon Bay showed that juvenile salmonids were feeding on *Jassa* sp., a tube dwelling amphipod that inhabits flotsam and pilings. The forage fish were feeding on water column organisms rather than benthic infauna organisms identified in Half Moon Bay. Of the flatfish, only the English sole showed evidence of feeding on intertidal benthic community organisms. Half Moon Bay does not appear to be a significant feeding area for juvenile Chinook salmon during their outmigration.

Benthic sampling methods described in this study provide an effective approach for assessing the impact of breach fill maintenance on benthic habitats in coarse grained sediments. Recommendations for additional data analysis and program enhancements are described below.

RECOMMENDATIONS

The following recommendations would allow for a greater understanding of the dynamics of the benthic communities at Half Moon Bay and refine the sampling approach developed for this pilot study. A third sampling event is tentatively scheduled for the early summer of 2005, which could help isolate the potential effects of seasonal recruitment and settlement of juvenile organisms on the study results.

- One limitation with the current study is the lack of replication at several of the stations in the study area. Normality testing of the data indicated that stations with three replicate sample results were non-normally distributed. However, stations with ten replicates appear to be normally distributed and parametric testing could be conducted. For the sake of comparability, all statistical testing in this study was conducted using nonparametric tests. Since ten replicates were collected at all stations, it is recommended that the remaining seven replicates be processed and analyzed. If this is not feasible, the remaining replicates should be carefully archived for future processing.

- For future studies of this type, consideration should be given to sampling at quarterly intervals.

- In future studies, sediment samples to measure the amount of total organic carbon (TOC) should be collected and analyzed. In coarse grained habitats such as those at Half Moon Bay and South Beach, TOC could help explain the benthic community distribution patterns observed at the intertidal content stations. TOC information would also assist in the evaluation of South Beach as a reference site.

- Although South Beach is located near Half Moon Bay, the differences in physical characteristics (open coast, gently sloping beach) are such that it may not be a suitable reference site for Half Moon Bay. Identification of a reference site within Half Moon Bay that is not affected by beach fill maintenance could provide relevant information on seasonal benthic community patterns.

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